

**WORK PHASE DETERMINATION FOR MACHINE TOOLS WITH SPINDLES,  
AND DEVICE THEREFOR**

**FIELD OF THE INVENTION**

This invention relates to a work phase determination method for machine tools with spindles and a device therefore.

**BACKGROUND OF THE INVENTION**

There is a machine tool in which a spindle housing supporting a specifically directed spindle for rotation alone is supported for parallel motion in orthogonal three-axis directions XYZ by a numerical control mechanism (see, for example, Japanese Patent Publication No. 2001-9652).

In the machine tool, a work support-feeding device that feed-rotates a work around a specific axis is provided, and machining is carried out by feed-rotating the work at a specific angle position therearound.

To perform such a machining, it is necessary to accurately determine a phase for the work around the specific axis on the work support-feeding device. Therefore, a reference tool for phase determination is formed and installed to the spindle, and thereon, a phase determination operation is performed so as to abut the work. After the operation, the tool is detached from the spindle and stored in a specific position. (See, for example, Japanese Patent No. 3083776.)

In the above-mentioned conventional work phase determination method, working efficiency falls because the operation of mounting/dismounting the reference tool on the spindle is required. In addition, it is uneconomical because a storage space for the reference tool is required. Moreover, there is some fear for shortening a bearing life because a load acts on a bearing rotation-freely supporting the spindle when the work abuts against the reference tool.

The present invention aims to settle the above-mentioned problems.

## SUMMARY OF THE INVENTION

To achieve the above-mentioned aims, in the present invention of process, in a machine tool having a spindle in which a spindle housing supporting the specifically directed spindle for rotation alone is supported for parallel motion in orthogonal three-axis directions XYZ by a numerical control mechanism, in determining the phase for the work to be feed-rotated around a specific axis, it is arranged that with a reference block comprising a board member in square at side sight fixed to the periphery of the front end of the spindle housing so as to forwardly protrude a little from the front end of the spindle housing, the work is feed-rotated around the specific axis to abut the phase reference section of the work against the reference block, so as to find the amount of feed-rotation (a phase angle  $\theta$  of a chuck part) of the work at the time of this abutment.

In this invention, the reference block remains being fixed on the spindle housing, and such a construction can be simple and inexpensive. In addition, when operating so as to decide a phase around the specific axis of the work, an enforcing power isn't given from the work to the spindle. Accordingly, the bearing life for rotation-freely supporting the spindle can be prolonged.

More specifically, the reference block comprising a board member in square at side sight, which is fixed right under the spindle so as to forwardly protrude a little from the front end of the spindle housing, is provided with a first plane perpendicular to a direction of the spindle and a second plane parallel to both of the direction of the spindle and the specific axis, in determining the phase for the work to be feed-rotated around the specific axis, the work is normally or reversely feed-rotated around the specific axis to abut the phase reference section of the work against each of the first plane and the second plane, so as to find the amount of feed-rotation (phase angles  $\theta_1$ ,  $\theta_2$  of the chuck part) of the work at the time of the abutments.

In this invention, the following effect can be given in addition to the above-mentioned effects. That is, the determination of a phase for the work around the specific axis by using the first plane and the second plane improves the accuracy of the determination thereof.

In these inventions, a crankshaft is suitable for the work, and in this case, a crank

pin can be used as the phase reference section. According to this, the above-mentioned effects can be given in the determination of the phase for crankshaft, and besides, using the crank pin for the phase reference section can dispense with preparing a special phase reference section.

In the present invention of device, in a machine tool in which a spindle housing supporting a specifically directed spindle for rotation alone is supported for parallel motion in orthogonal three-axis directions XYZ by a numerical control mechanism, a special reference block in which a phase reference section of a work feed-rotated around a specific axis by the numerical control mechanism abuts is fixed on the reference block. This invention contributes to carrying out the invention of process.

More specifically, in the machine tool in which the spindle housing supporting the specifically directed spindle for rotation alone is supported for parallel motion in orthogonal three-axis directions XYZ by the numerical control mechanism, the special reference block is fixed on a specific position with relation to the spindle and the spindle housing, whereas a work support-feeding device for feed-rotating the work around the specific axis perpendicular to the direction of the spindle, and a work phase deciding means for determining a phase for the work around the specific axis based on the amount of feed-rotation around it when the phase reference section feed-rotated around it abuts against the reference block displaced to a phase adjustment position with reference to the work in advance is provided. This invention contributes to understanding the amount of feed-rotation of the work by reciprocally rotating the work around the specific axis.

In this case, the work support-feeding device comprises an intermediate table in rectangle at plan sight fixed horizontally, a work driving table fixed on an end of the top face of the intermediate table, and a push table fixed on the other end thereof. In addition, the work driving device has an NC table installed to have a table main body fixed on the intermediate table, and besides, has a driving center for supporting a chuck portion supported on the table main body and rotatively driven around a specific axis of the X-axis direction by the NC table and rotation center of an end face of the work grasped by the chuck portion. Moreover, the special reference block is constructed as follows. That is, the reference block in the present invention comprises a board

member in square at side sight forward-protrusively fixed a little from the front end of the spindle housing with a spindle, and the board member is provided with a first plane perpendicular to the direction of the spindle and a second plane parallel to both of the direction of the spindle and the specific axis.

In this invention, the phase for the work around the specific axis is determined by abutting the phase reference section of the work to either of the first plane and the second plane. Besides, when the phase reference section of the work is abutted to both of the first plane and the second plane, the phase for the work around the specific axis

can be decided accurately regardless of an error in its finishing dimension.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side view of a machine tool with a spindle of the present invention, in which a part is shown in a section.

Fig. 2 is a plane view of the machine tool, and Fig. 3 is a view showing a section taken on line X1-X1 in Fig. 2.

Fig. 4 is a view showing an operating flow sheet of the present invention, and Fig. 5 is a view showing an operating flow sheet next to the operating flow sheet in Fig 4.

Fig. 6 is an explanatory view showing a situation that a crank pin is abutted to the first plane of a reference block of the machine tool. Fig.7 is an explanatory view showing a situation that a crank pin is abutted to the second plane of the reference block. Fig. 8 is an explanatory view of a modification concerning a phase adjustment position of the reference block.

## PREFERRED EMBODIMENT OF THE PRESENT INVENTION

An explanation about the present invention will follow with reference to figures.

In Figs. 1 to 3, 1 is a bed, and thereon, are provided a fixed column 2, a work support-feeding device 3, a numerical control mechanism 4 and hydropneumatic equipment 5.

A cylindrical spindle housing 7 rotation-freely supporting a longitudinally directed spindle 6 (in a Z-axis direction) is mounted to the fixed column 2 feed-displaceably in an X-axis direction, a Y-axis direction and the Z-axis direction forming orthogonal three-axis directions. A cutting tool 8 is fixed to a front end of the spindle 6.

A reference block 9 is forward-protrudently fixed to the lowest position of a front outer peripheral face of the spindle housing 7 below the spindle 6. The reference block 9 comprises a front face 9a and a lower end face 9b. Here, the front face 9a forms a first plane perpendicular to the Z-axis direction, and the lower end face 9b forms a

second plane parallel to both of the Z-axis direction and the X-axis direction.

The work support-feeding device 3 comprises a horizontal rotating table 12, an intermediate table 13, a work drive table 14 and a center push table 15. The rotating table 12 is feed-rotated around a Z-axial directed rotation support axis 11 by a servomotor 10 provided to the bed 1. The intermediate table 12 is horizontally fixed on the rotating table 12. The work drive table 14 is fixed on one end side of an upper face of the intermediate table 13, and the push table 15 is fixed on the other end side thereof.

In this case, the work drive table 14 is provided with a table main body 17, a chuck portion 18 and a driving side center 18. The table main body 17 is fixed to the intermediate table 13 and has a NC (numerical control) table 16 installed. The chuck portion 18 is supported on the table main body 17 to be rotatively driven around a specific axis S of the X-axis direction by the NC table 16. The driving center 19 is supported on the table main body 17 and located on the specific axis S, supporting a rotating center of an end face of a work w grasped by the chuck portion 18. The chuck portion 18 has a plurality of claws 18a for grasping a work as shown in Fig. 3.

The center push table 15 is provided with a table main body 20 fixed to the intermediate table 13, a drive device 20 of the X-axis direction mounted on the table main body 20 and a push center 21. The push center 21 is slidably-displaceably supported on the table main body 20 and push-moved by the drive device 20a to support the rotating center of the other end face of the work w.

In the above-mentioned machine tool, an example of operations before a crankshaft of the work w is started machining will be explained with reference to Figs. 4 to 7. Here, Fig. 4 and Fig. 5 show operating flow sheets. Fig. 6 is an explanatory view showing a situation that a crank pin w is point-abutted to the first plane 9a of a reference block 9. Fig. 7 is an explanatory view showing a situation that the crank pin w is point-abutted to the second plane 9b of the reference block 9.

First, in step S100, necessary data about the shape of the work w, position of the reference block 9 and programs for determining a phase and for machining the work w are input from an input device of the numerical control mechanism 4. Here, the

numerical control mechanism 4 has these data memorized on its memory portion.

Next, in step S101, the numerical control mechanism 4 has the servomotor 10 operate according to the necessity. That is, the rotation support axis 11 is feed-rotated, the horizontal rotation table 12 rotates, and two centers 19, 21 are positioned on the specific axis S. Besides, the NC table 16 is operated according to the necessity, and therefore, the chuck portion 18 is feed-rotated, and a radial line of the chuck portion agreed with a table phase reference p0 is made a phase zero position reference k1 thereof as shown in Fig. 3. Here, the phase zero position reference k1 is an imagined one fixedly specified on the chuck portion 8, and the table phase reference p0 is an imagined one fixedly specified on the table main body 16.

Thereafter, the work w is loaded between the centers 19, 21 by a robot, an automatic feed device or manual controls and the like, and its position is temporarily kept. In this case, although it is taken care that the phase of the work w around the specific axis S and the phase of the chuck portion 18 therearound closely resemble each other, it is not done to accurately match these phases because the loading must be rapidly operated. Accordingly, the phase zero position reference k1 of the chuck portion 18 and a phase reference k2 of the work w (a work phase reference) are usually shifted somewhat around the specific axis S. In this example, the work phase reference k2 is shifted from the phase zero position reference k1 of the chuck portion 18 to the contrary rotation side of the chuck portion 18 by an angle  $\theta$  0. Here, the phase reference k2 is an imagined one fixedly specified on the work w.

Next, in step S102, the drive device 20a displaces one center 21 to the other center 19 and puts these centers 19, 21 into center holes comprising conical female faces formed to end faces of the work w, respectively. Therefor, the work w is supported by the centers 19, 21, and thereafter, the work w is released from keeping position due to the robot, the automatic feed device or the manual controls and the like so as to protect the circumference thereof from the after operation. Then, the drive device 20a has the center 21 push to the center 19 by further strong forth. Therefor, the work w is surely put between the centers 19, 21 to have the rotation center agree with the specific axis S

exactly. In addition, at the same time, one end face of the work  $w$  is pushed to a work longitudinal reference face 18b formed near the center of the chuck portion 18 and perpendicular to the specific axis  $S$ , and the position on the specific axis  $S$  direction is fixed. Under the situation, the claws 18a clamp the outer periphery of one end of the work  $w$ .

Thereafter, in step S103, the program for determining a phase is started. The numerical control mechanism 4 displaces the spindle housing to the predetermined position, and the reference block 9 is displaced and stopped to the phase adjustment position  $p2$ . In the displaced reference block 9, the center on the X-axis direction is positioned at the about center of the length of a specified crank pin  $w1$ . Besides, as shown in Fig.6, an intersection point  $p3$  between the first plane 9a and the second plane 9b is turned to a radial direction of the specific axis  $S$  and situated on the Z-axis and the Y-axis to be positioned on a line  $L1$  inclined in right rise by  $45^\circ$  against these axes. Moreover, the first plane 9a and the second plane 9b are respectively positioned on a rotation displacement locus of the crank pin  $w1$  around the specific axis  $S$ . Besides, the phase adjustment position  $p2$  showing an example can be exchanged to another position suitably. This will be described later in detail.

Next, in step S104, the NC table 16 is operated to feed-rotate the work  $w$  in a normal rotation direction around the specific axis  $S$  with the chuck portion 18. When the crank pin  $w1$  abuts to the first plane 9a of the reference block 9 as shown in Fig. 6, the detection is performed to stop the NC table 16 from operating. In this case, the rotation angle  $\theta 1$  of the chuck portion 18 at the time of this abutment is recognized and memorialized in the numerical control mechanism 4. The rotation angle  $\theta 1$  is an angle from the table phase reference  $p0$  to the phase zero position reference  $k1$  of the chuck portion 18 at the time of the abutment.

In this case, the abutment between the crank pin  $w1$  and the first plane 9a is detected directly by a torque sensor when torque transmitted from the work drive portion 14 to the chuck portion 18 increases or indirectly by a drive amperometry of the work drive portion 14. Besides, it can be detected by a proximity sensor or an air pressure



sensor provided to the reference block 9.

Next, in step S105, it is discriminated whether a high-accurate operation will be required in the operation of determining the phase for the work. In this case, the standard for discrimination depends on the operator's optional will.

When it is decided that the high-accurate operation is unnecessary, the process is displaced to step S106, whereas when it is decided that the operation is necessary, the process is displaced to step 107.

In the step S106, the rotation angle of the work w in after adjusting the phase is corrected in accordance with the rotation angle  $\theta 1$  of the chuck portion 18 at the time of the abutment between the reference block 9 and the crank pin w1.

Fully, the rotation angle  $\theta 1$  is calculated by data such as a rotation radius around the specific axis S at the center of the crank pin w1, a diameter of the crank pin and position of the first plane 9a of the reference block 9. Here, the calculated rotation angle from the table phase reference p0 of the chuck portion 18 is assumed to be  $\theta 10$ .

Next, the rotation angle  $\theta 10$  is deducted from the rotation angle  $\theta 1$  of the chuck portion 18 calculated in the step S104. Thus calculated difference value  $\theta 12$  agrees with the angle  $\theta 0$  from the work phase reference k2 to the phase zero position reference k1 of the chuck portion 18 if there is no machining error. And this is handled as a phase shift angle between the chuck portion 18 and the work w, and made the amount of correction in determining the phase for the work w. Accordingly, a rotation angle  $\theta t$  of the chuck portion 18 for determining the phase for the work w, such as rotating the work phase reference k2 from the table phase reference p0 by a specified angle  $\theta w$  only, is calculated by the following formula (1). Here, the rotation angle  $\theta t$  is what the phase zero position reference k1 of the chuck portion 18 rotates from the table phase reference p0 to the normal rotation direction f1.

$$\theta t = \theta w + \theta 12 \quad \cdots \cdots \cdots \text{Formula(1)}$$

According to the formula (1), when positioning the work w to the place of an optional specified angle  $\theta w$  in the after work machining, the rotation angle  $\theta t$  requires the size adding the difference value  $\theta 12$  to the angle  $\theta w$ . This operation is

automatically carried out by the numerical control mechanism 4.

In case determining the phase for the work w like this, when the shape data input into the numerical control mechanism 4 exactly agree with the actual work w, the phase for the work w around the specific axis S can be exactly determined. However, for example, when the diameter of the crank pin w1 is different from the input shape data, an error is to be caused in proportion to the difference. In addition, when there are unintentional irregularities on the periphery of the crank pin w1, an error is to be caused in proportion to the dimensions thereof in the radial direction.

On the other hand, when it is displaced to step S107, the following operation will be carried out.

The NC table 16 is operated in the reverse direction to the case in the step S104, and the work w is feed-rotated with the chuck portion 18 in a reverse rotation direction f2 around the specific axis S. And, when the crank pin w1 abuts to the second plane 9b of the reference block 9 as shown in Fig. 7, the detection is performed, and thereafter, the operation is stopped. A rotation angle  $\theta 2$  from the table phase reference p0 of the chuck portion 18 at the time of the abutment is recognized and memorized into the numerical control mechanism 4. The rotation angle  $\theta 2$  is an angle from the table phase reference p0 to the phase zero position reference k1 of the chuck portion 18 at the time of the abutment.

In this case, the abutment between the crank pin w1 and the first plane 9a can be detected in the same way with the case of the step S104.

Next, in step S108, an angle value  $\theta 3$  is calculated by dividing the value adding the rotation angle  $\theta 1$  in the step S104 and the rotation angle  $\theta 2$  in the step S107 by 2.

Lastly, it is displaced to step S109, and therein, the angle value  $\theta 3$  is memorized into the numerical control mechanism 4, and based thereon, the rotation angle of the work w in after determining the phase for the work w can be corrected.

Further specifically, the rotation angle  $\theta 2$  of the chuck portion 18 at the time of the abutment between the reference block 9 and the crank pin w1 in the step S108 is calculated by data such as the rotation radius around the specific axis S at the center of

the crank pin w1, the diameter of the crank pin w1, and the position of the first plane 9a of the reference block 9. Here, the calculated rotation angle from the table phase reference p0 of the chuck portion 18 is assumed to be  $\theta 20$ .

Next, a difference value  $\theta 22$  is calculated by adding the rotation angle  $\theta 20$  and the rotation angle  $\theta 10$ , dividing it by 2, and subtracting the divided angle value from the angle value  $\theta 3$ . The value  $\theta 22$  accurately agrees with the angle  $\theta 0$  from the work phase reference k2 to the table phase reference p0 when the phase zero position reference k1 of the chuck portion 18 agrees with the table phase reference p0. Therefore, the value  $\theta 22$  is handled as the phase shift angle between the chuck portion 18 and the work w to be made the amount of correction in determining the phase for the work w. Accordingly, the rotation angle  $\theta t$  of the chuck portion 18 for an operation to determine the phase for the work w, such as rotating the work phase reference k2 from the table phase reference p0 by a specified angle  $\theta w$  only, is calculated by the following formula (2).

$$\theta t = \theta w + \theta 22 \quad \dots\dots\dots \text{Formula(2)}$$

According to the formula (2), when positioning the work w to the place of an optional specified angle  $\theta w$  in the after work machining, the rotation angle  $\theta t$  requires the size adding the difference value  $\theta 22$  and the angle  $\theta w$ . This operation is automatically carried out by the numerical control mechanism 4.

In this operation, even if the diameter of the crank pin w1 is different from the shape data input into the numerical control mechanism 4, the work w can be positioned to the place of a wishful angle  $\theta w$  without receiving influences due to the error. Even if the crank pin w1 is machined in a section of polygonal shape by a crank shaft mirror or has unintentional irregularities on the periphery, the degree of influence that the error of the diameter of the crank pin w1 exerts on positioning the work w to the place of the wishful angle  $\theta w$  is greatly reduced. Therefore, the work w is positioned to the place of the wishful angle  $\theta w$  more accurately than the case of the step S106.

In the operations at all steps of the above-mentioned example, it can be suitably decided which of operations will be operated by hand and which of operations will be

automatically carried out.

A modification of the above-mentioned example will be explained as follows with reference to Fig. 8 and the like. Here, Fig 8 is an explanatory view showing a modification concerning a phase adjustment position p2 of the reference block 9.

(1) In the above-mentioned example, the intersection point p3 of the reference block 9 is turned to the radial direction of the specific axis S and situated on the Z-axis and the Y-axis to be positioned on the line L1 inclined in right rise by  $45^\circ$  against these axes. In this case, although the correction amount in determining the phase for the work w can be calculated only by displacing the reference block 9 to the phase adjusting position p2 at a time, this method is not necessarily best to keep the accuracy. Therefore, to improve the accuracy in determining the phase for the work, the operations may as well be performed as follows.

That is, as shown in Fig. 8, the reference block 9 is arranged to the place where the periphery of the crank pin w1 point-abuts to the first plane 9a when the work phase reference k2 agrees with the table phase reference p0, and the operation in the step S104 is carried out to detect the rotation angle  $\theta 1$  of the chuck portion 18. In addition, the reference block 9 is arranged to the place where the periphery of the crank pin w1 point-abuts to the second plane 9b when the work phase reference k2 rotates from the table phase reference p0 to the reversal direction f2 by  $270^\circ$ , and the operation in the step S107 is carried out to detect the rotation angle  $\theta 2$  of the chuck portion 18.

According to this, one end p4 of the specified diameter line d1 of the crank pin w1 abuts to the first plane 9a and the other end p5 thereof abuts to the second plane 9b. Accordingly, an error in the diameter direction of the crank pin w1 is surely eliminated, thereby improving the accuracy for determining the phase for the work w.

(2) In the step S104, although the difference value  $\theta 2$  is calculated by point-abutting the periphery of the crank pin w1 to the first plane 9a, the periphery may be point-abutted to the second plane 9b instead of the first plane 9a.

(3) When calculating the rotation angles  $\theta 1$  and  $\theta 2$  of the chuck portion 18, the reference block 9 can be arranged to a suitable place excepting the above-mentioned

position within the range of the present invention.

According to thus constructed invention, the following effects can be given.

The usual operation of mounting/dismounting the reference tool on the spindle 6 is dispensed with, thereby improving the work efficiency. In addition, the usual storage space for the reference tool is dispensed with, thereby achieving an inexpensive structure. Moreover, since the enforcing force of the work w does not directly influence the spindle 6, the life of the bearing for supporting the spindle 6 can be prolonged.

Furthermore, the following effects can be given in addition to the above-mentioned effects. The accuracy for determining the phase for the work w can be improved by using the first plane 9a and the second plane 9b. For example, even if the finishing accuracy of the diameter of the crank pin w1 is different from every work w, the phase for the work w can be decided exactly. In addition, for example, even if the work w includes the crank pin w1 machined by the crankshaft miller to be microscopically shaped in a polygon, the phase for the work can be decided accurately.

In addition, also in determining the phase for the crankshaft w1, such effects can be given. Moreover, the phase for the crankshaft w1 can be decided without the special phase reference section due to using the crank pin w1 as a work phase reference section.

Furthermore, the phase for the work w around the specific axis S can be decided easily and flexibly due to using the first plane 9a or the second plane 9b. In addition, it can be decided accurately in spite of the finishing dimension error of the phase reference section w1 of the work w by abutting the phase reference section (the crank pin w1) of the work w to both of the first plane 9a and the second plane 9b.